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Goosen et al.

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(54) **STATIC CLASSIFIER**

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(Continued)

(56) **References Cited**

U.S. PATENT DOCUMENTS

1,385,846 A * 7/1921 Sturtevant B07B 4/025
209/139.2
1,709,848 A 4/1923 Hardinge
(Continued)

FOREIGN PATENT DOCUMENTS

EP 0 204 412 A2 2/2016
GB 2 132 920 A 7/1984

OTHER PUBLICATIONS

International Search Report for PCT/IB2014/064310 dated Mar. 11, 2015.

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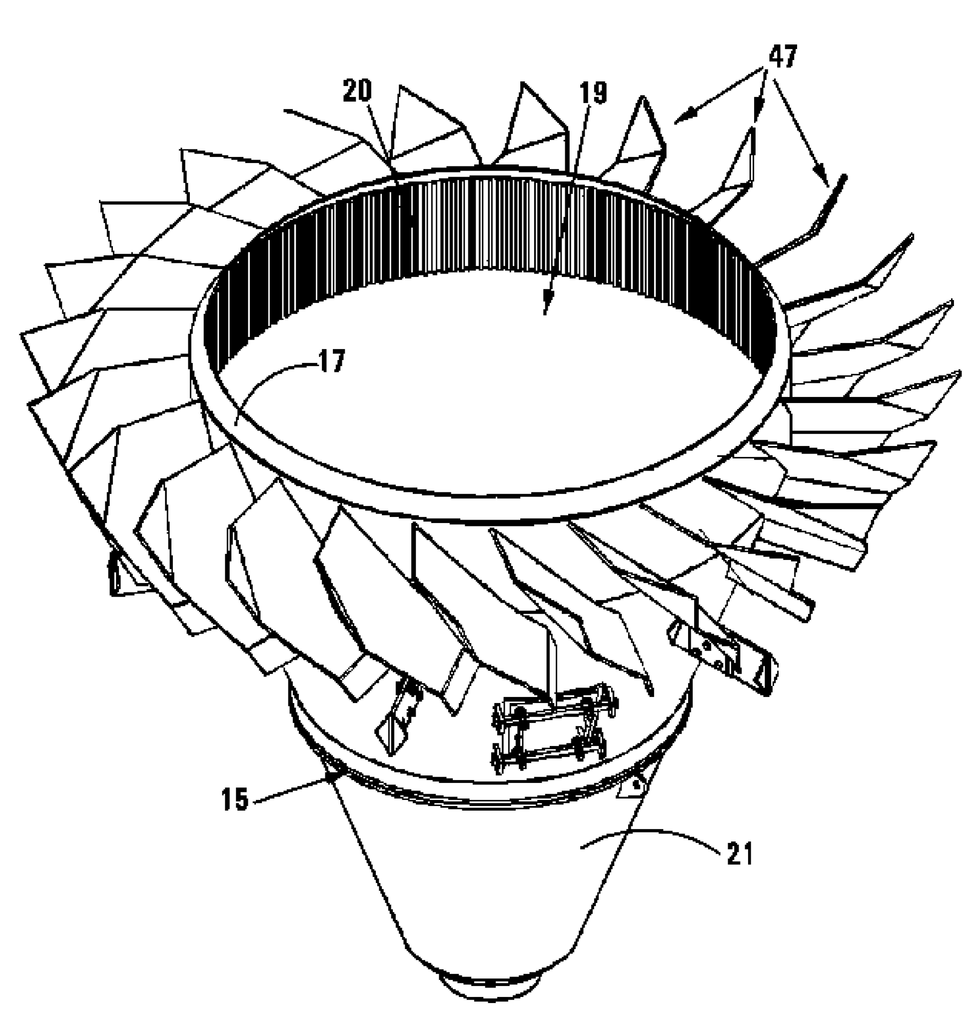
(57) **ABSTRACT**

Classifier (**10**, **100**, **200**) which is configured to classify air-entrained, crushed particulate material received from a pulverizer into a fine fraction which is expelled from the classifier (**10**) and a coarse fraction which is returned to the pulverizer for further crushing. The classifier (**10**) includes a plurality of adjustable inlet blades (**37**) which are arranged partially above an inlet (**20**) leading into a classification zone (**19**), an angle of the blades (**37**) being adjustable through manipulation of a blade adjustment mechanism (**39**) in order to optimize particle flow conditions inside the classifier (**10**). Furthermore, the classifier (**10**) includes a plurality of inclined pre-swirl vanes (**47**) which are disposed below the inlet blades (**37**), each vane (**47**) having a curved body. The classifier (**100**) includes a part conical member (**102**) which
(Continued)



is suspended below an operatively upper exit (**31**) leading from the classification zone (**19**).

14 Claims, 11 Drawing Sheets

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B02C 23/12 (2006.01)
B07B 7/083 (2006.01)
(58) **Field of Classification Search**
USPC 209/718
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

1,470,892	A *	10/1923	Sturtevant	B07B 4/025	209/139.2
4,693,811	A *	9/1987	Lohnherr	B07B 4/025	209/139.2
5,667,149	A *	9/1997	Eisinger	B02C 15/001	241/119
5,819,947	A	10/1998	Nardi et al.		
5,957,300	A *	9/1999	Nardi	B02C 15/001	209/139.2
6,409,108	B1 *	6/2002	Wark	B02C 15/001	241/119
6,827,221	B1 *	12/2004	Brundiek	B02C 23/16	209/208
8,033,399	B2 *	10/2011	Pistorius	B07B 7/08	209/142
8,453,846	B2 *	6/2013	Baetz	B04C 5/12	209/139.1
8,622,328	B2 *	1/2014	Matsumoto	B07B 7/02	241/119
8,651,032	B2 *	2/2014	Otani	B02C 15/04	110/232
8,813,967	B2 *	8/2014	Plant	B07B 7/02	209/139.1
8,915,373	B2 *	12/2014	Lin	B23P 17/04	209/139.1
9,259,739	B2 *	2/2016	Aizawa	B02C 15/007	
2002/0178698	A1 *	12/2002	Oh	A47L 9/1666	55/337
2012/0012687	A1 *	1/2012	Vierstra	B02C 23/10	241/79
2012/0138718	A1	6/2012	Daimaru et al.		
2015/0314330	A1 *	11/2015	Huang	B07B 7/083	241/47

* cited by examiner

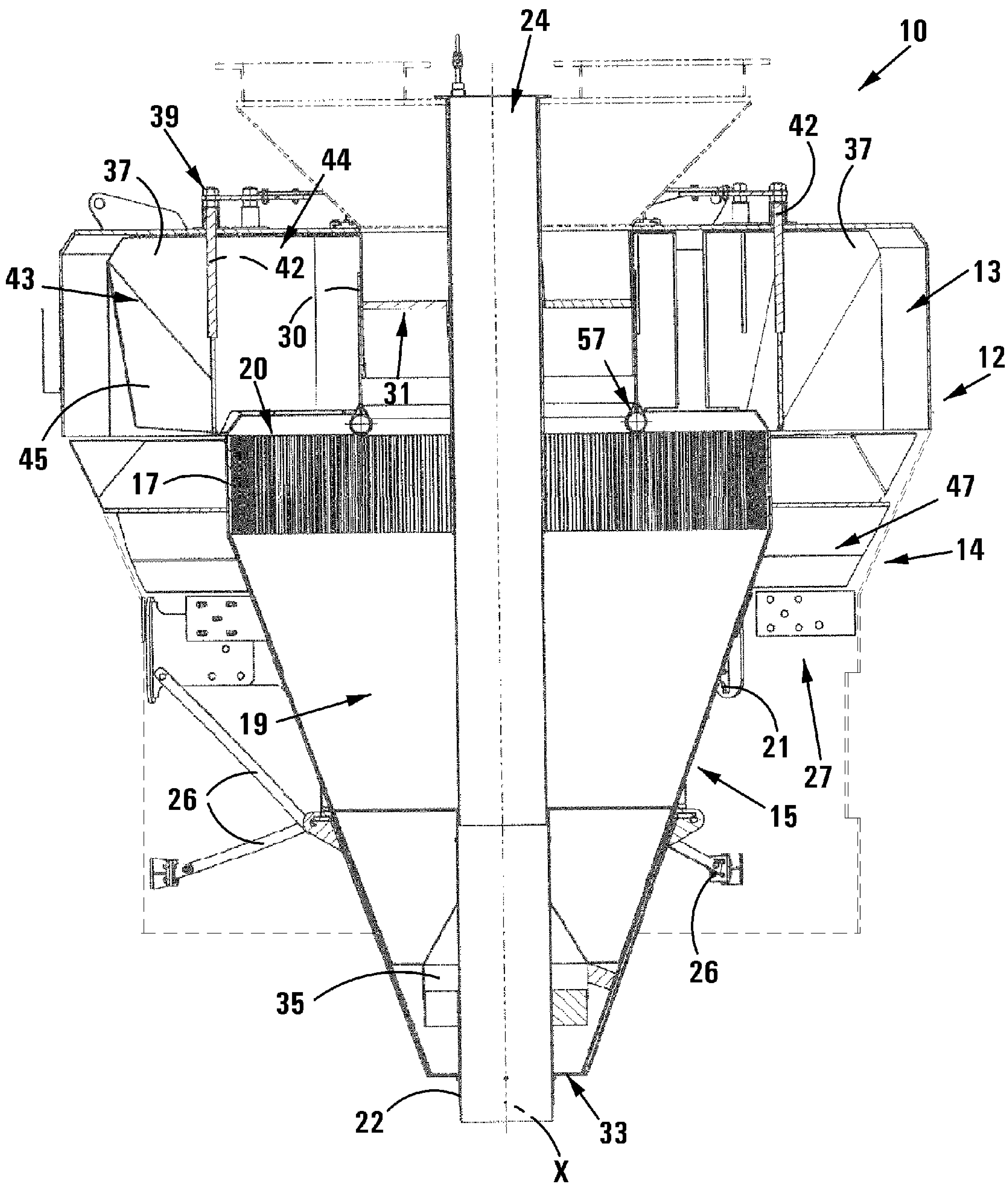
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FIG 1

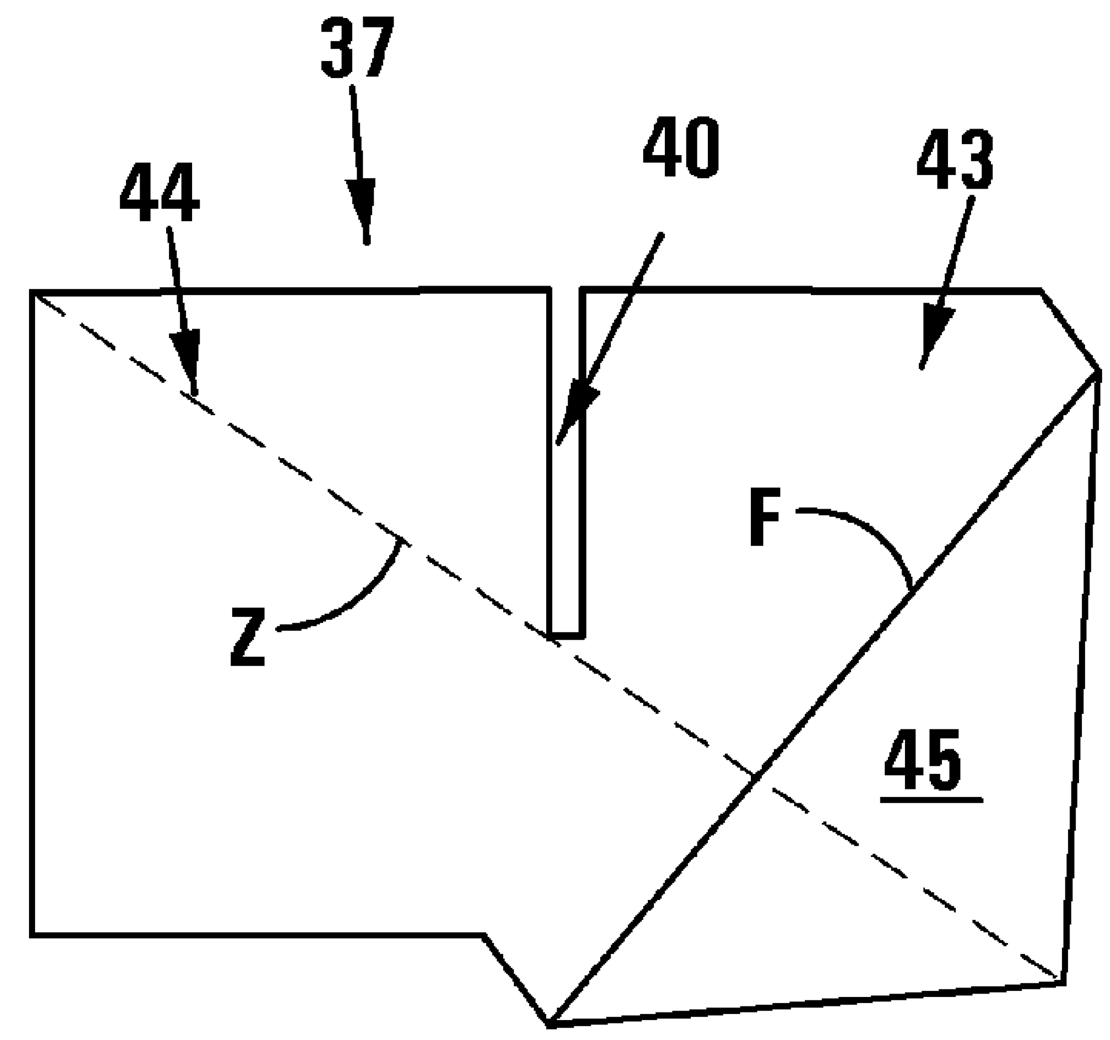
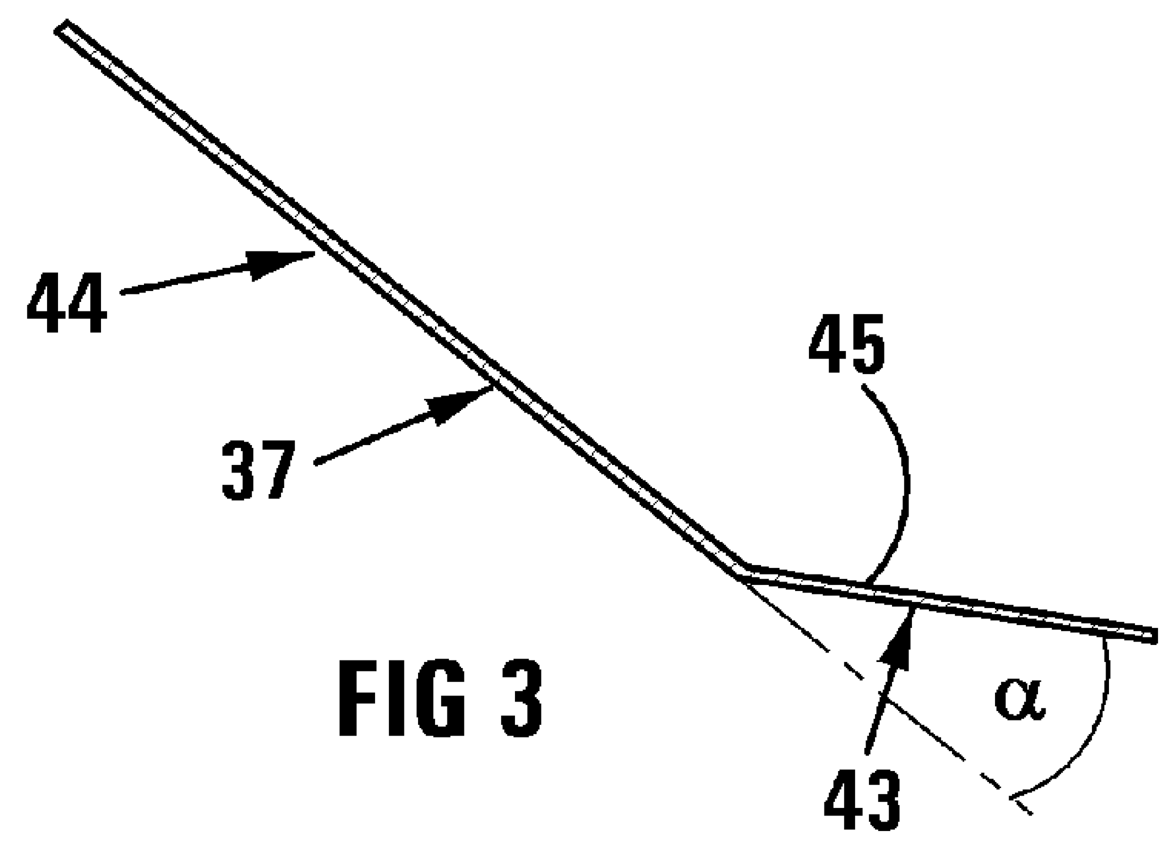


FIG 2



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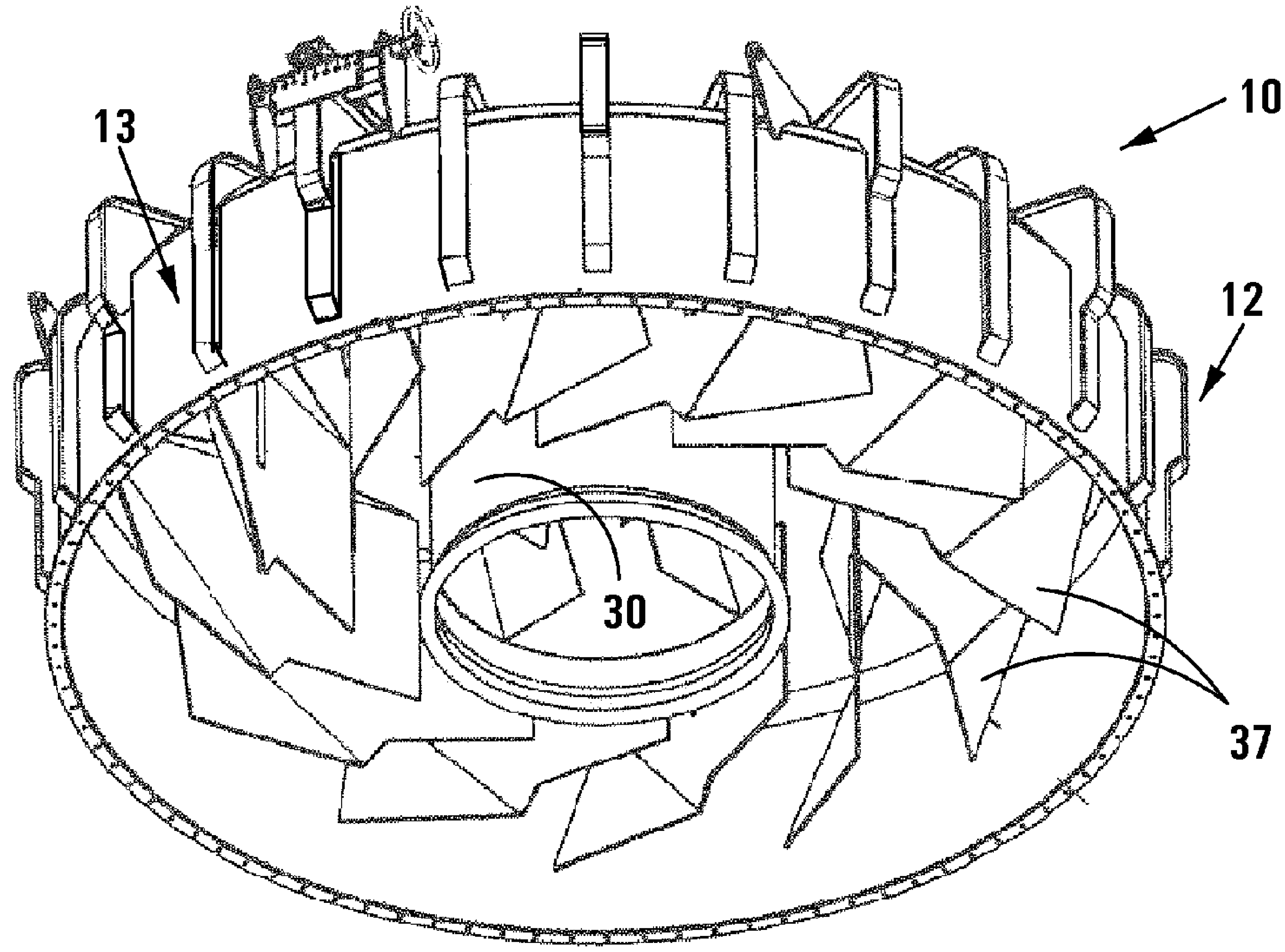

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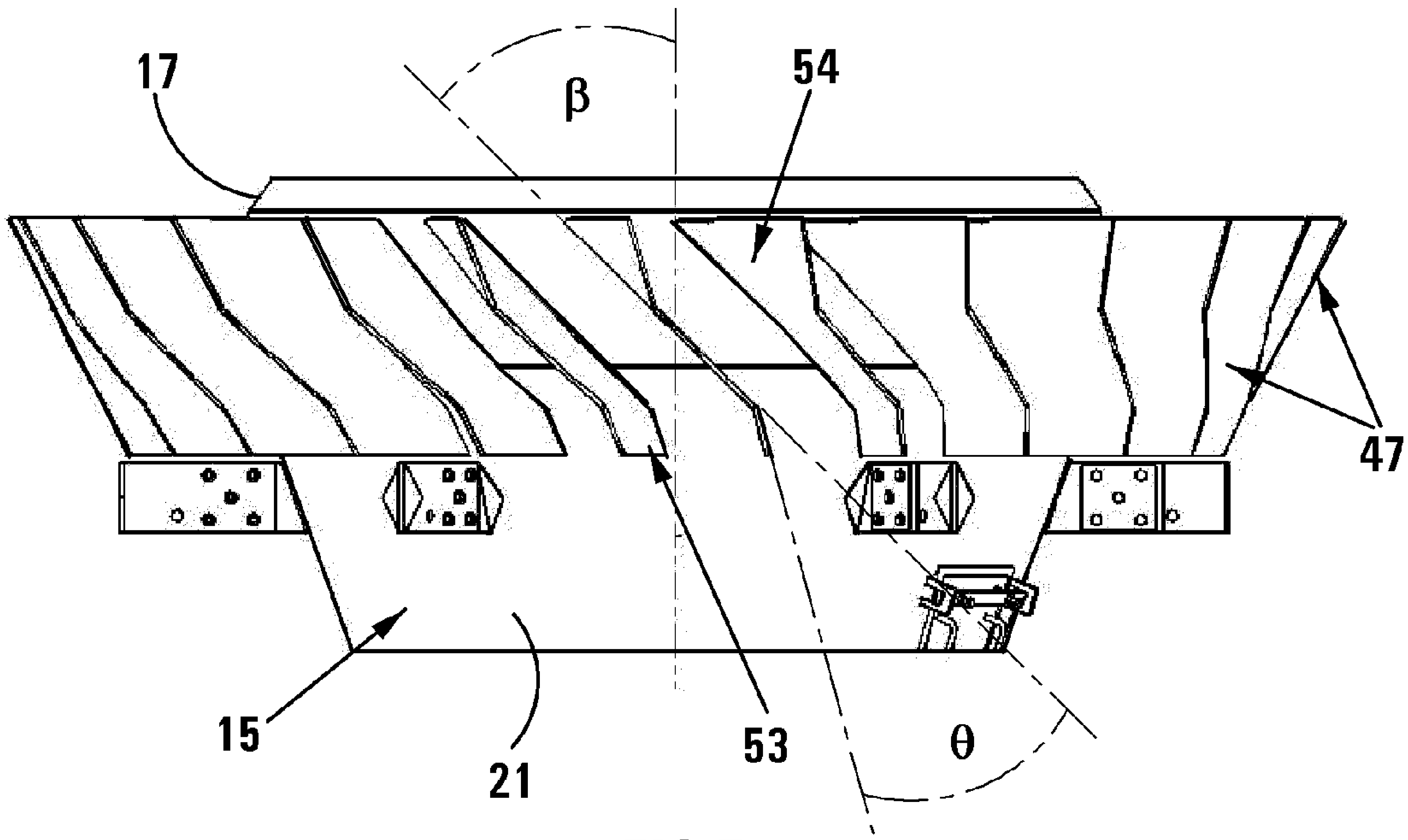


FIG 5

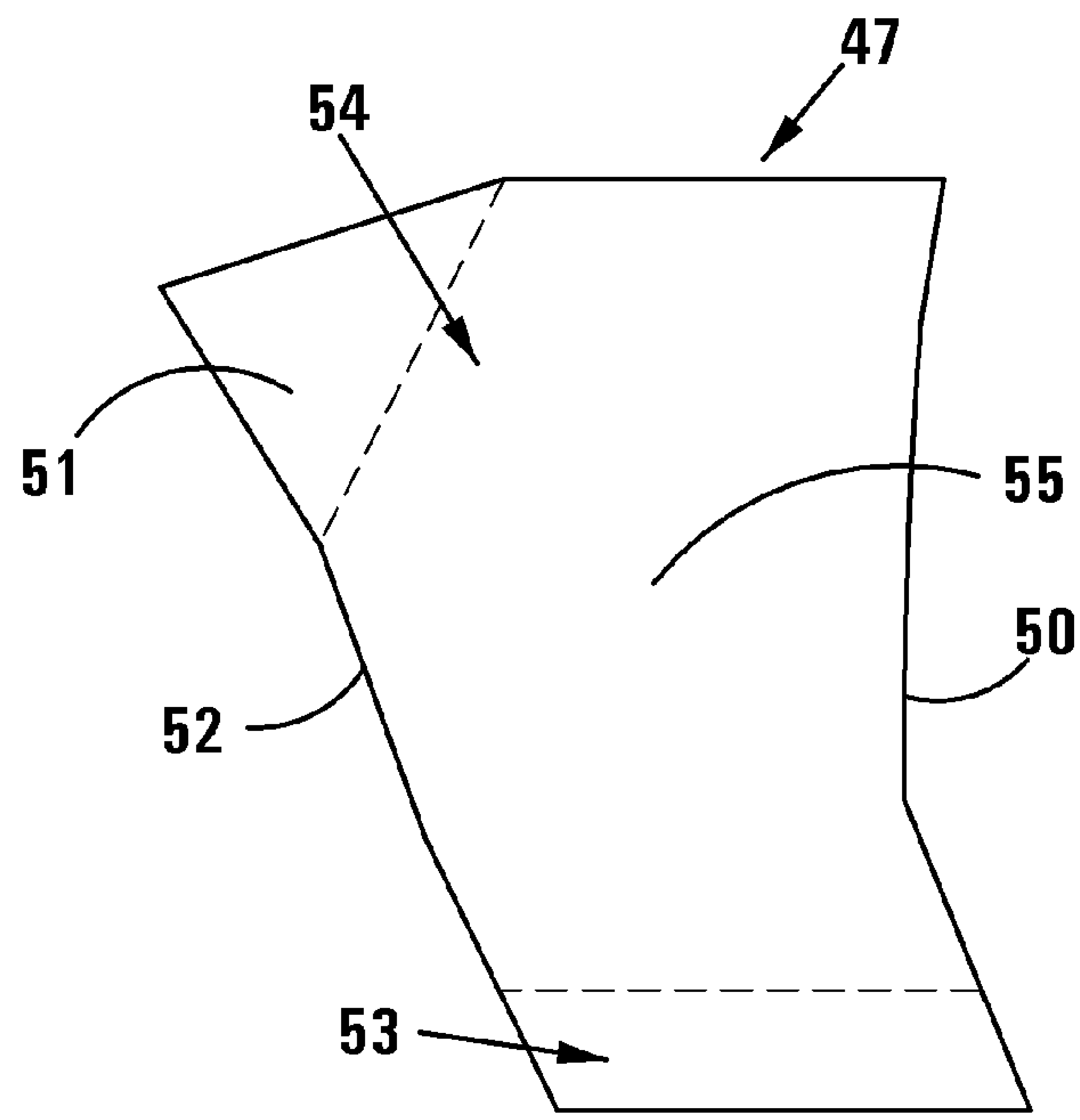


FIG 6

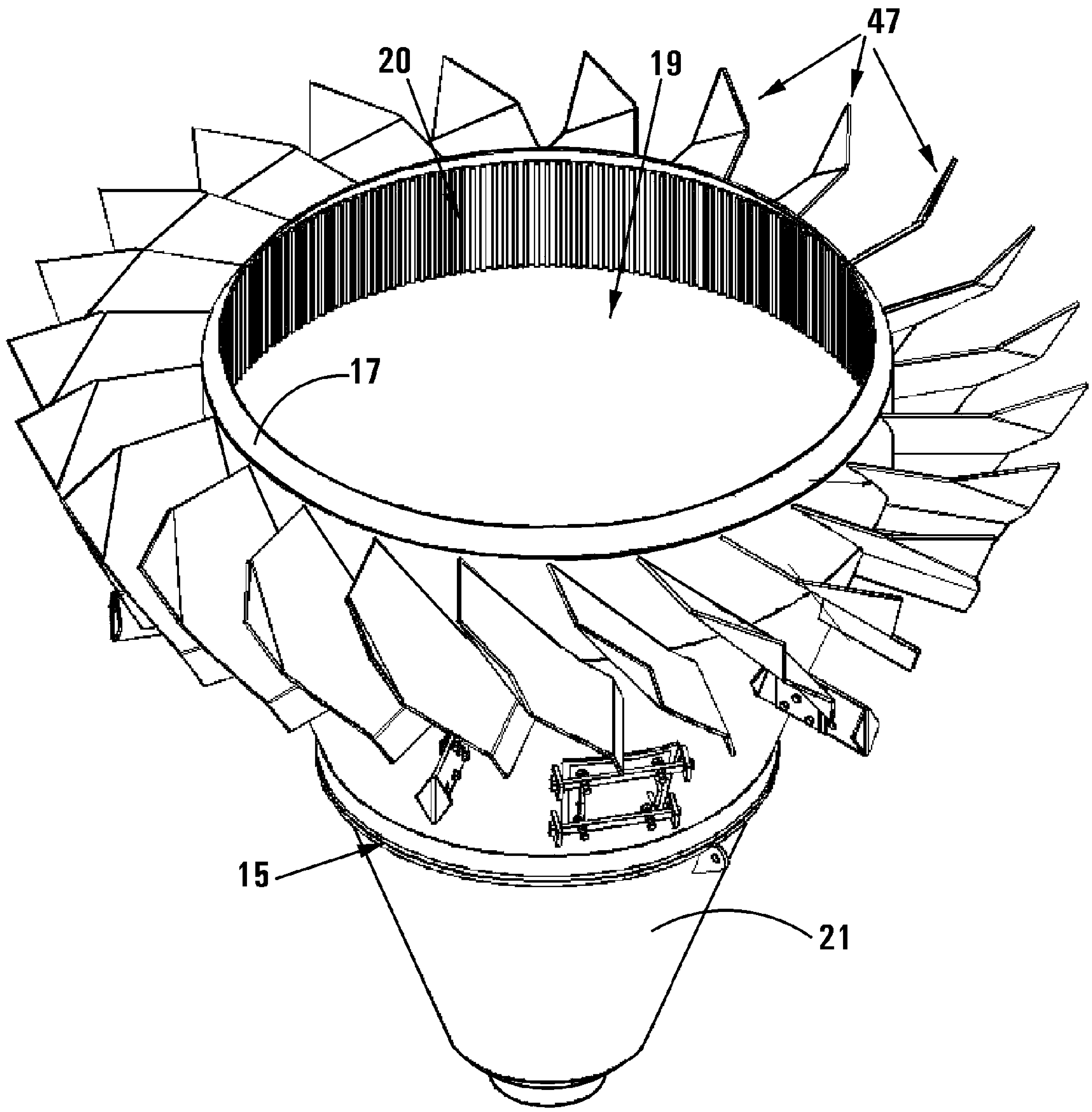


FIG 7

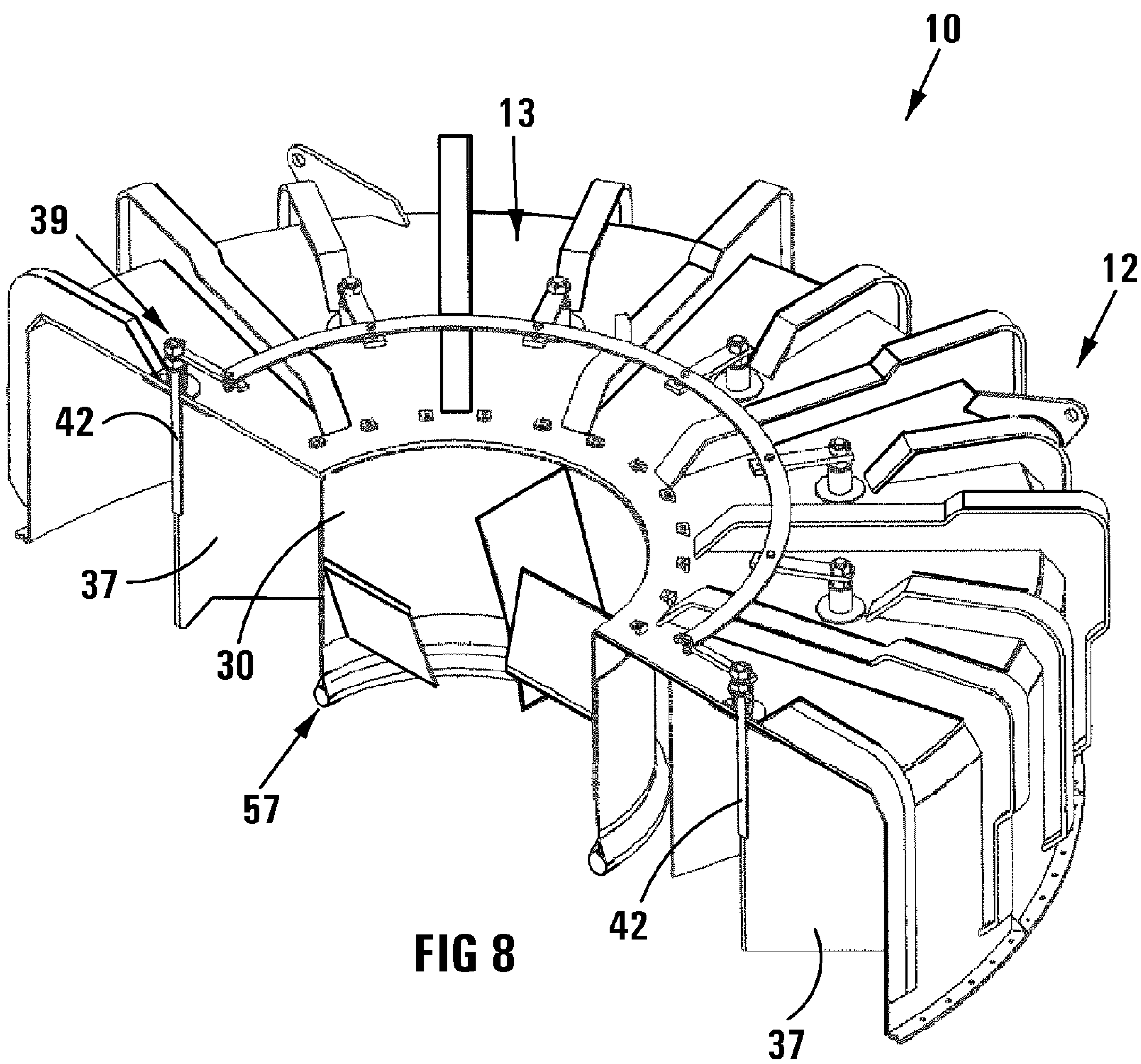
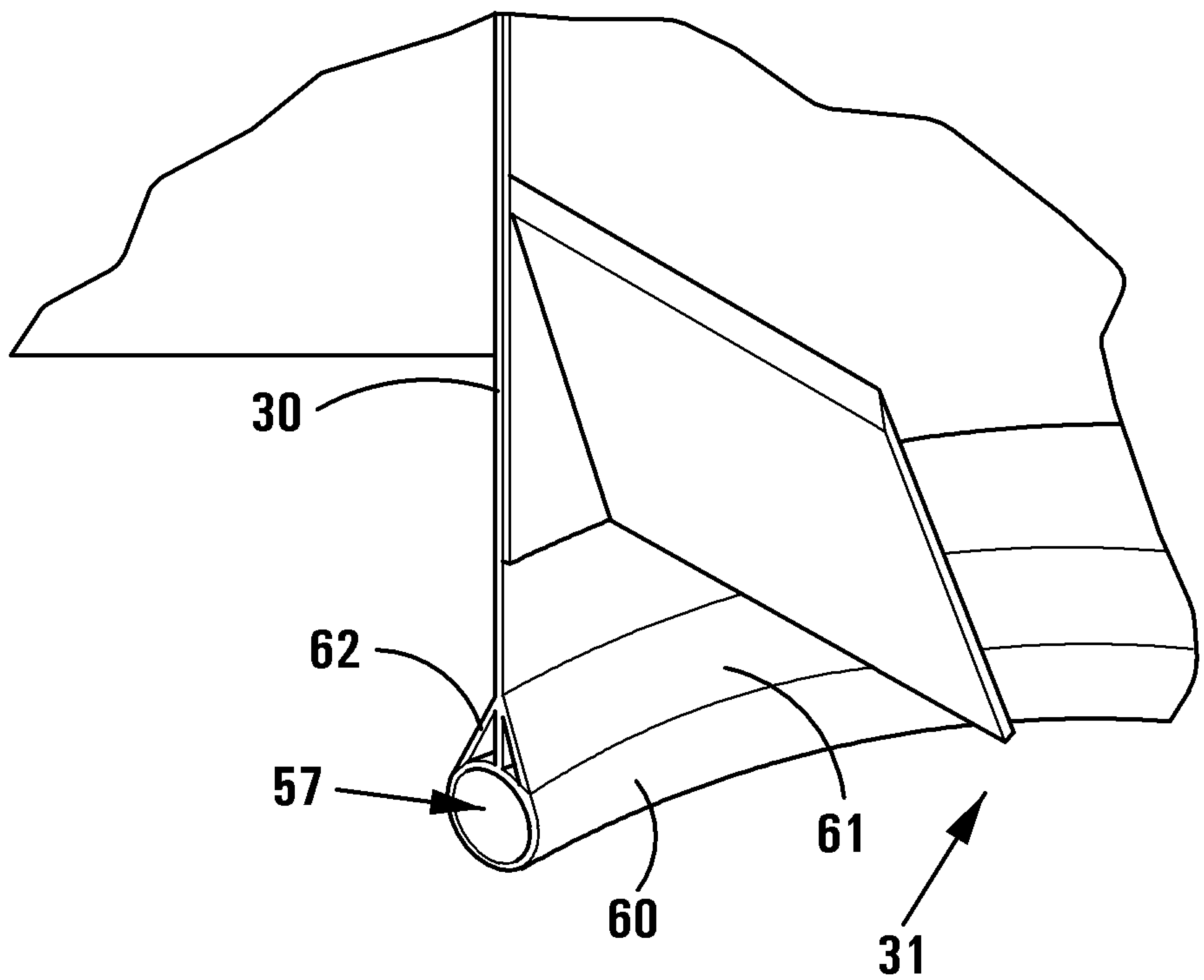


FIG 8



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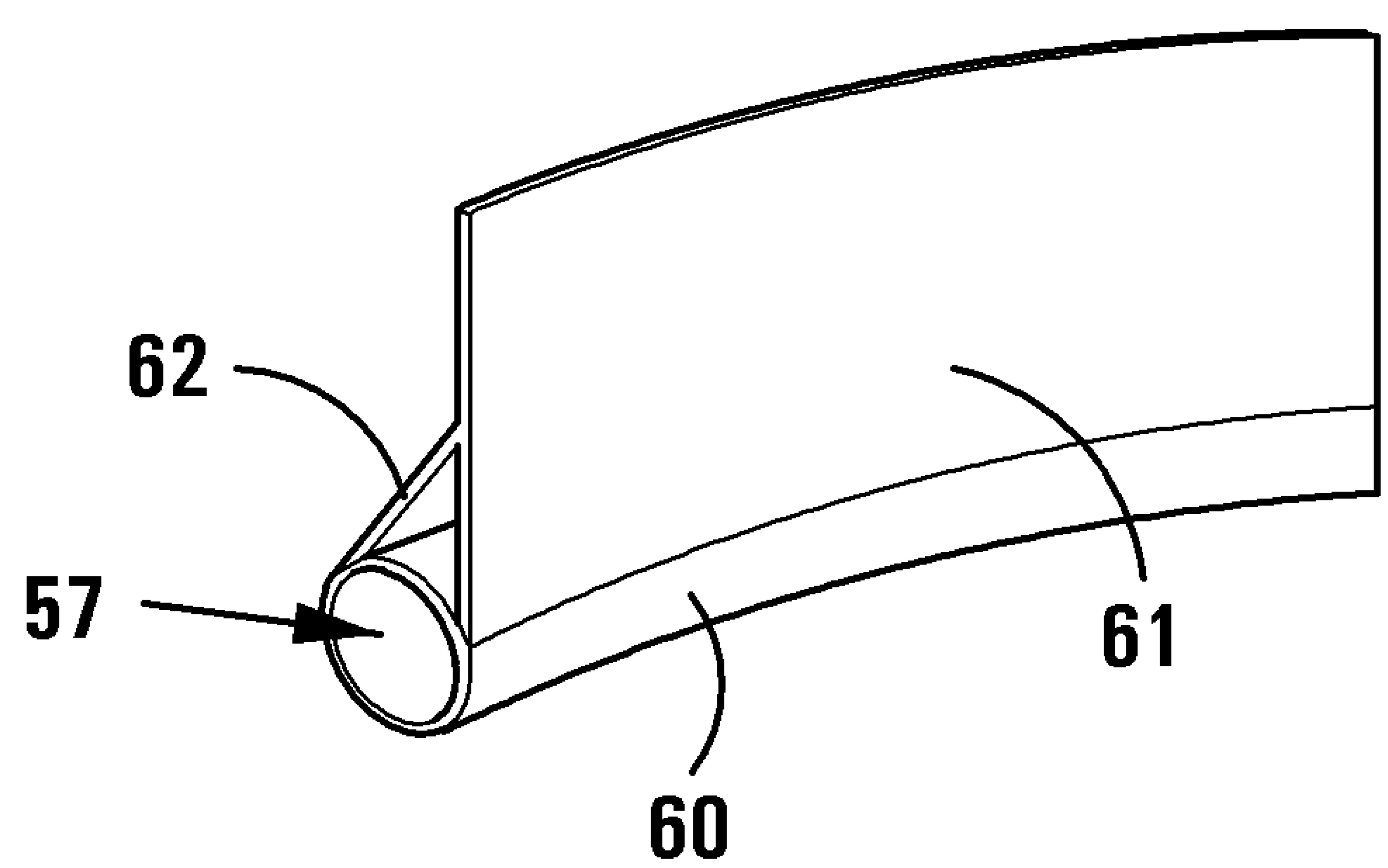

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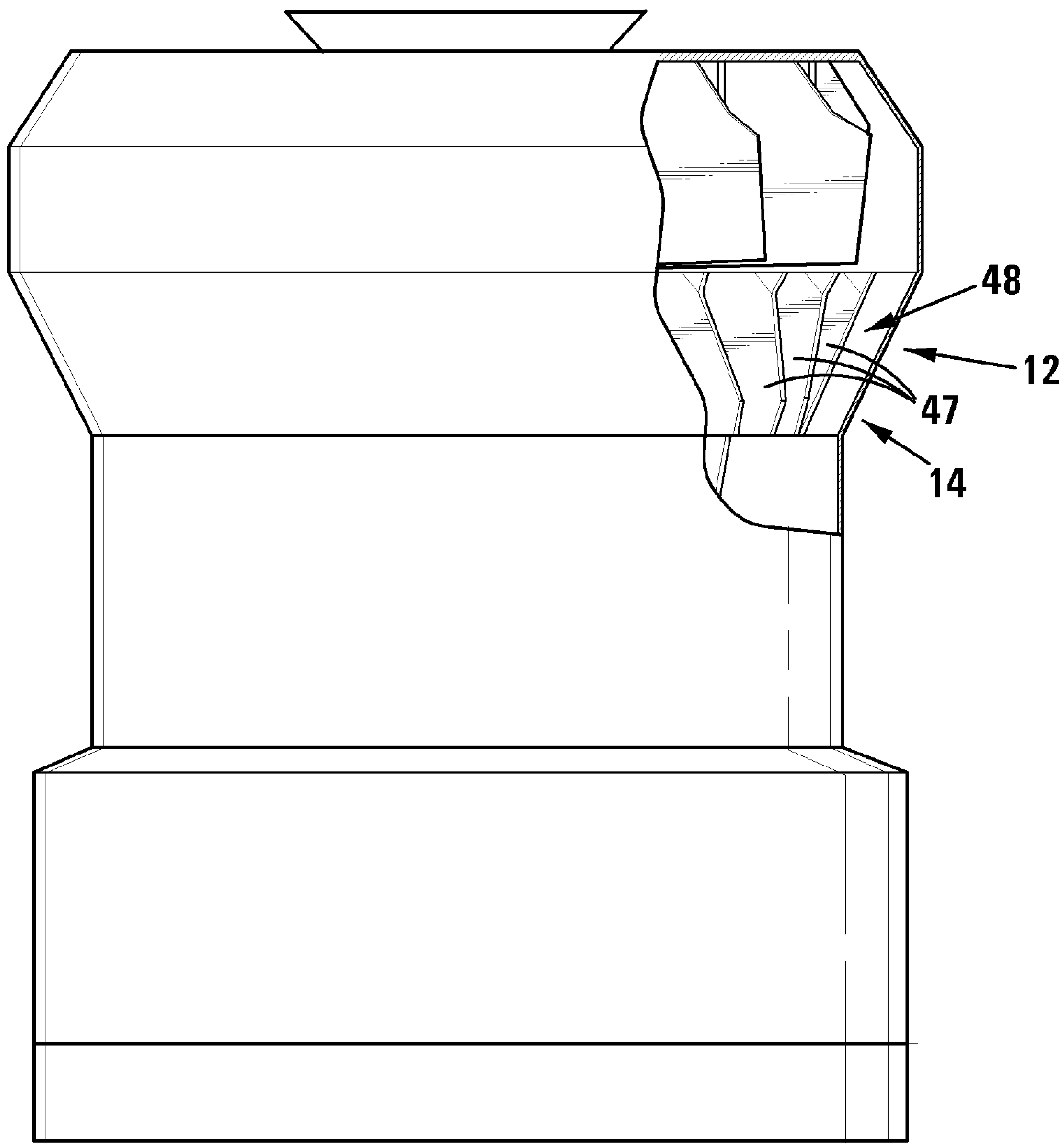

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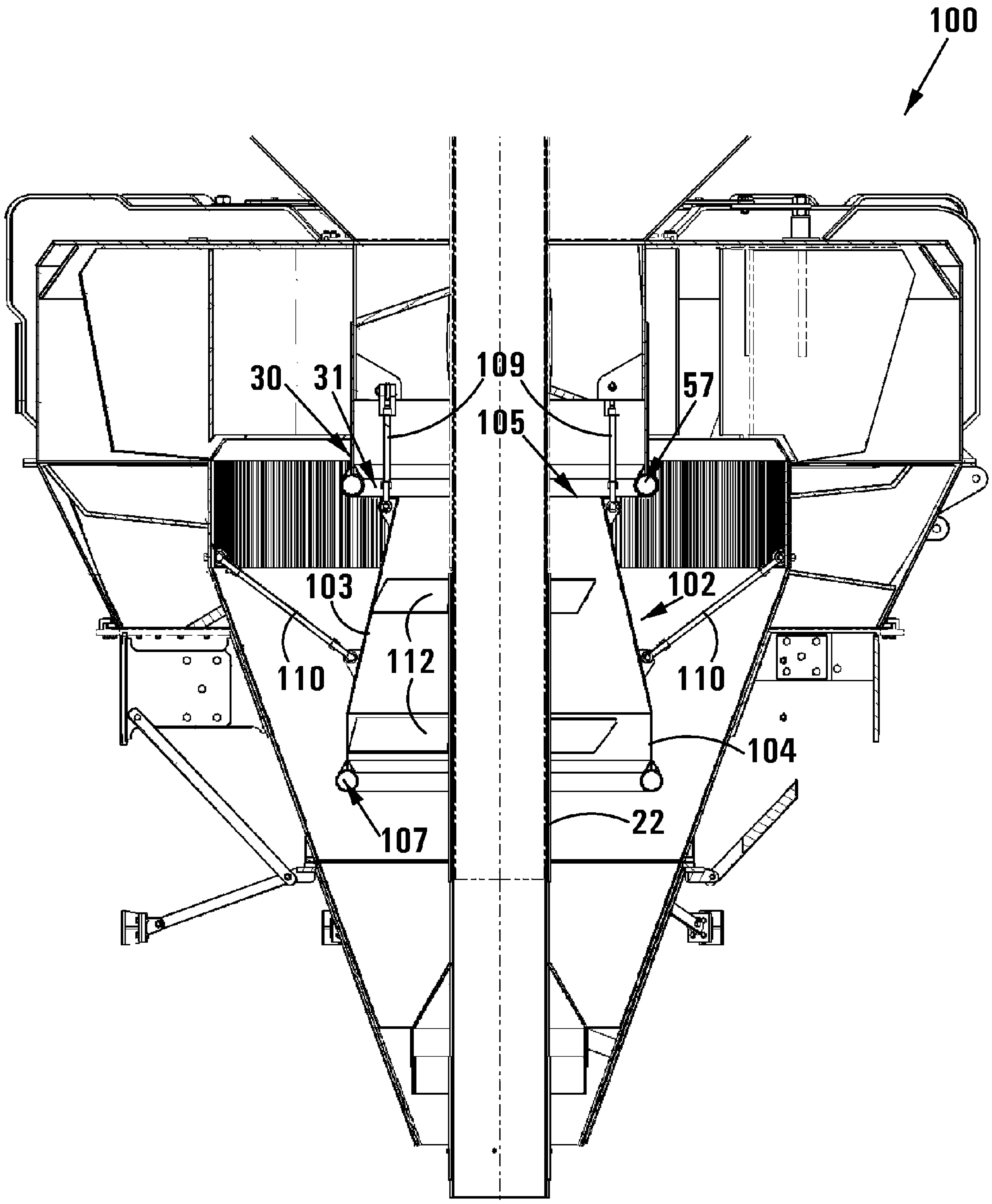

FIG 12

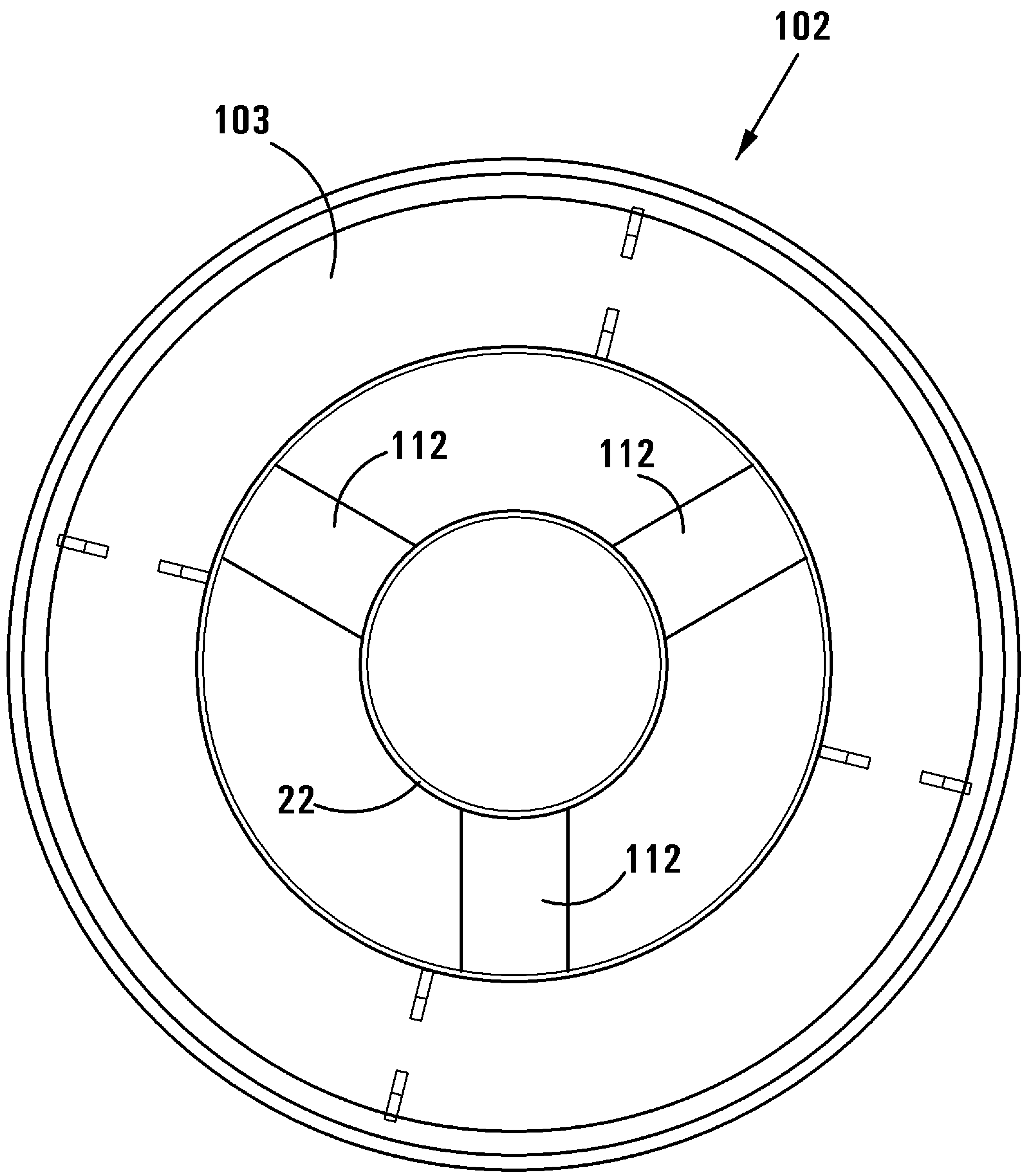

FIG 13

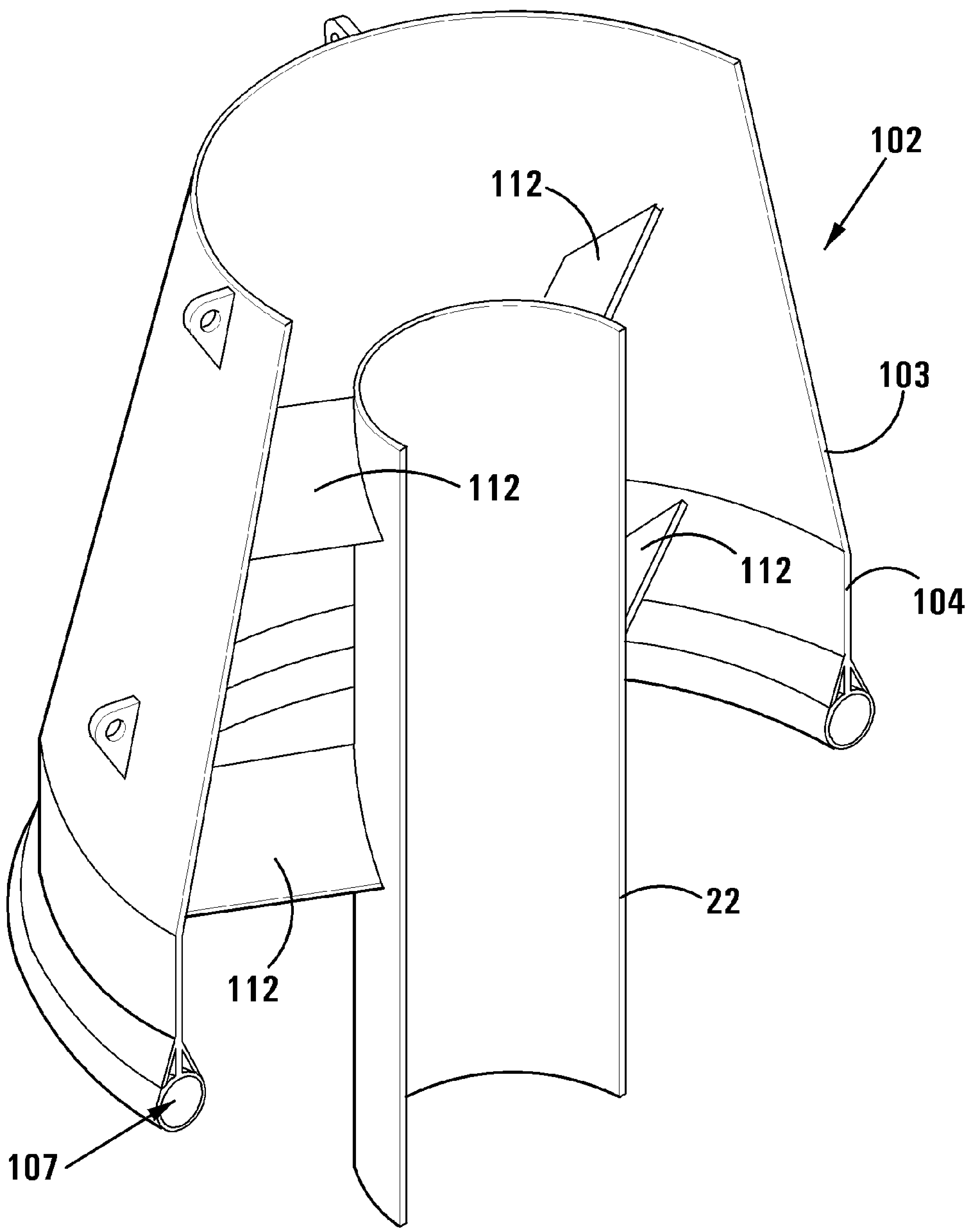

FIG 14

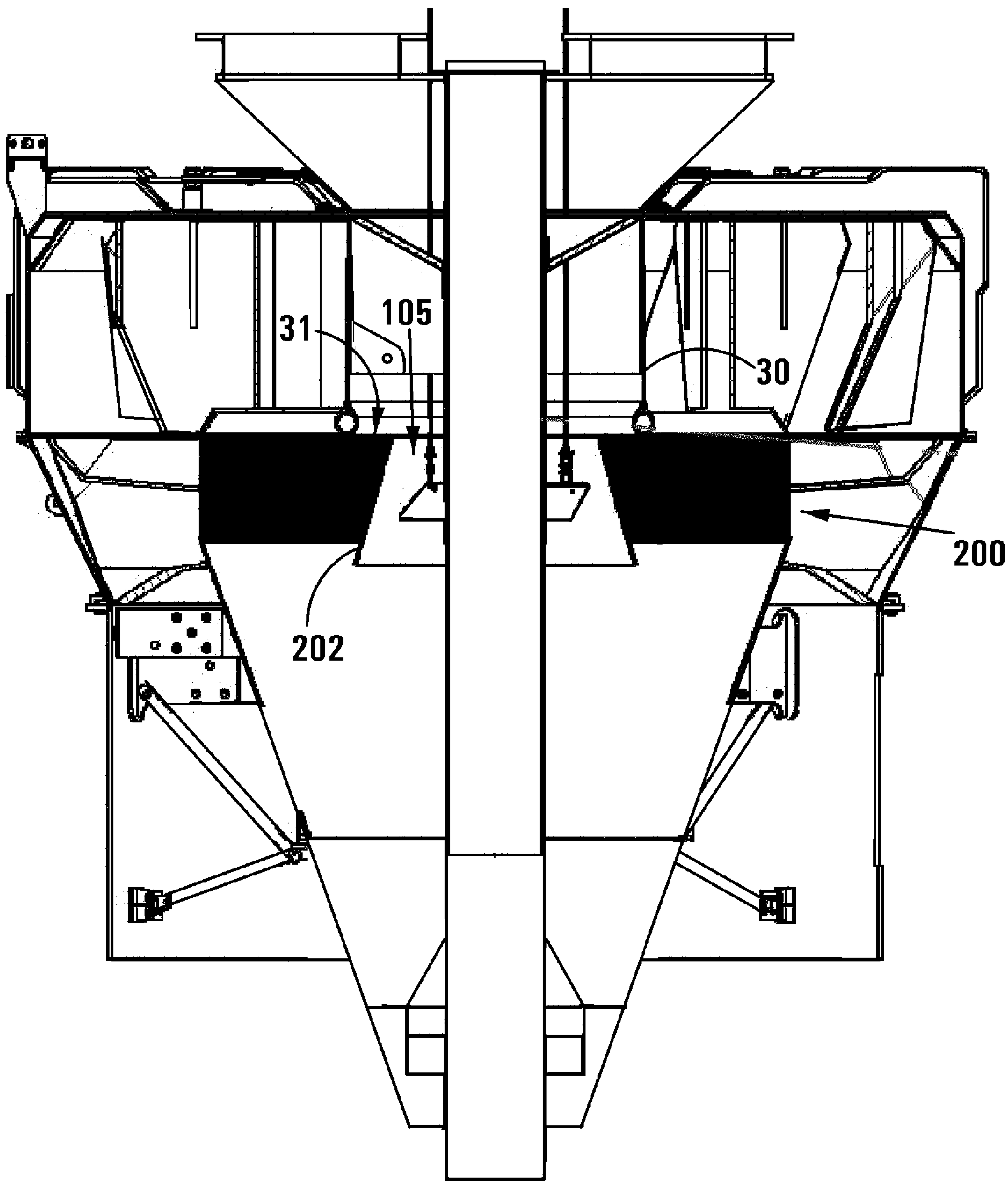

FIG 15

STATIC CLASSIFIER

CROSS REFERENCE TO RELATED APPLICATIONS

This application is a U.S. National Phase Application of PCT International Application Number PCT/IB2014/064310, filed on Sep. 8, 2014, designating the United States of America and published in the English language, which is an International Application of and claims the benefit of priority to South African Patent Application No. 2013/06762, filed on Sep. 9, 2013. The disclosures of the above-referenced applications are hereby expressly incorporated by reference in their entireties.

FIELD OF INVENTION

This invention relates to a pulveriser or mill used to crush or grind raw material such as coal, for example, into fine particles suitable for combustion in steam-generating furnaces of fossil fuel power plants. More particularly, this invention relates to a classifier used in conjunction with such a pulveriser for classifying crushed particulate material received from the pulveriser into a sufficiently fine fraction which is suitable for combustion and a coarse fraction which is rejected and returned to the pulveriser.

BACKGROUND OF INVENTION

Pulverisers are commonly used for crushing large coal or other raw material into small particles. An airstream entering the pulveriser sweeps the particles into a classifier which separates coarse particles from the airstream for regrinding and allows the finer particles to exit the classifier and to be used in a process or burned in a furnace (in the case of coal). Prior art classifiers in some cases are not as effective in returning the coarse particles or are less efficient owing to increased flow resistance caused by turbulence in certain areas within the classifier. Increased turbulence is undesirable as the classifier parts are subjected to increased wear. These inefficiencies limit the capacity of the pulveriser and negatively affect the output of boilers fed by the pulveriser (in the case of coal). Latest boiler requirements for NO_x reduction require a finer product than previous type classifiers were designed for. The Inventors desire an improved static classifier which can provide the fineness required in these boilers for low NO_x design burners whilst maintaining throughput of these mills.

The Inventors desire a classifier which addresses the above drawbacks.

SUMMARY OF INVENTION

In accordance with a first aspect of the invention, there is provided a classifier for use with a pulveriser which is configured to crush raw material, the classifier being configured to classify air-entrained, crushed particulate material received from the pulveriser into a fine fraction which is expelled from the classifier and a coarse fraction which is returned to the pulveriser for further crushing, the classifier including:

a housing defining:

an inward classification zone;

an upwardly open inlet through which the entrained crushed particulate material received from the pulveriser enters the classification zone;

an operatively upper exit and an operatively lower outlet which lead from the classification zone; and

a plurality of adjustable classifier inlet blades which are arranged at or near the inlet, each adjustable blade including a body which comprises an operatively upstream portion which is outwardly disposed away from the inlet and an operatively downstream portion which is disposed at least partially within and/or immediately above the inlet,

wherein at least part of the upstream portion of each adjustable blade is inclined with respect to the downstream portion of the blade body, the adjustable blades collectively being configured to induce swirl and to direct the entrained particulate material through the inlet into the classification zone.

The size of the area around the blades will be such as to supply a desired air/particle velocity. The Inventors believe the velocity will typically be between 4.5 and 5.5 m/s. However, this may vary depending on operating conditions. In general a velocity of about 4.5 m/s may be used where a high throughput classifier is desired and a velocity of about 5.5 m/s may be used where a high fineness product is required. The length of the adjustable blades may affect the velocity at the outlet of the blades and is therefore adjusted to meet operational requirements.

The classifier may be a static classifier and a corner of the upstream portion of each blade may be inclined at an angle of between 20° and 40° with respect to the downstream portion of the blade body when viewed edge-on from a bottom of the blade body.

The corner of the upstream portion may be separated from a remainder of the blade body by a fold line or bend line which is substantially perpendicular to a diagonal extending between a pair of opposing corners of the blade body. Each adjustable blade may include a mounting formation whereby the blade is mounted to the housing. Accordingly, the blade may be bent corner-to-corner. A remainder of the upstream portion and the downstream portion may be planar. A selection of the inclination of the angle of between 20° and 40° may depend on an expected turbulence behind the adjustable blades.

The classifier may include an inlet blade adjustment mechanism which is connected to the mounting formations of each of the blades in a configuration in which an angle of each blade body relative to the housing is adjustable in order to regulate air flow through the inlet, by adjusting the blade adjustment mechanism. In use, an air/particle velocity through the blades may be between 4.5 and 5.5 m/s.

The classifier may further include a plurality of angularly spaced apart, inclined pre-swirl vanes which are disposed upstream of the inlet blades, wherein each pre-swirl vane comprises a multi-planar body.

In accordance with a further aspect of the invention, there is provided a classifier for use with a pulveriser which is configured to crush raw material, the classifier being configured to classify air-entrained, crushed particulate material received from the pulveriser into a fine fraction which is expelled from the classifier and a coarse fraction which is returned to the pulveriser for further crushing, the classifier including:

a housing defining:

an inward classification zone;

an inlet through which the entrained crushed particulate material received from the pulveriser enters the classification zone; and

an operatively upper exit and an operatively lower outlet which lead from the classification zone;

- a plurality of classifier inlet blades which are arranged at or near the inlet; and
- a plurality of angularly spaced apart, inclined pre-swirl vanes which are disposed upstream of the inlet blades, wherein each pre-swirl vane comprises a multi-planar body.

The pre-swirl vanes may be disposed around an upper region of an outer periphery of walls of the housing defining the classification zone. The body of each vane may include an operatively upstream portion and an operatively downstream portion, the upstream and downstream portions being joined by a middle, wherein the upstream portion is downwardly inclined with respect to the middle such that the upstream portion is substantially parallel to an incoming air stream in order to minimise air flow resistance and wear; and at least part of the downstream portion is upwardly and inwardly inclined with respect to the middle and configured to direct fluid flow inward and to induce a centrifugal swirl. The upstream portion of each vane may be downwardly inclined at an angle of between 20° and 40° relative to the middle of the vane body and a fold line or bend line representing a start of the upstream portion may be parallel with a lower edge of the upstream portion. The size of an area around the pre-swirl vanes may be designed to match the air/particle velocity selected for the adjustable blades.

An outer corner of the downstream portion of each vane may be inclined at an angle between 20° and 40° with respect to the middle of the vane body. The selection of a bend angle of between 20° and 40° may be determined by analysing turbulence on a surface of the pre-swirl vanes. The middle of each vane body may be inclined at between 30° and 60° with respect to the vertical. Preferably each vane is inclined at 45° with respect to the vertical but this may depend on flow conditions within the classifier. The angle of the vanes with respect to the vertical may be calculated and modelled using fluid dynamics. Inner and outer edges of each vane may match profiles of neighbouring walls of the classifier and a gap may be defined between the outer edges of the vanes and a mill body, the gap being smaller than or equal to half a width of a pre-swirl vane. There may be at least one blade for every two pre-swirl vanes. The pre-swirl vanes may have vane-to-vane overlap of one third of at least a vane breadth.

A lower edge of the housing defining the upper exit may have an aerofoil or teardrop cross-sectional profile which is configured to reduce turbulence and flow resistance at the exit of the classifier.

The invention also extends to a classifier for use with a pulveriser which is configured to crush raw material, the classifier being configured to classify air-entrained, crushed particulate material received from the pulveriser into a fine fraction which is expelled from the classifier and a coarse fraction which is returned to the pulveriser for further crushing, the classifier including:

- a housing defining:
  - an inward classification zone;
  - an inlet through which the entrained crushed particulate material received from the pulveriser enters the classification zone; and
  - an operatively upper exit and an operatively lower outlet which lead from the classification zone, wherein a lower edge of the housing defining the upper exit has an aerofoil or teardrop cross-sectional profile which is configured to reduce turbulence and flow resistance at the exit of the classifier.

The classifier may include an open ended depending member which is at least partially disposed within the classification zone, the member having a narrow upper end and a lower end, the member diverging from the upper end toward the lower end, the upper end defining a mouth having a reduced cross-sectional area when compared with a cross-sectional area of the upper exit, wherein the upper end of the depending member is arranged within or below the upper exit.

In accordance with yet another aspect of the invention, there is provided a classifier for use with a pulveriser which is configured to crush raw material, the classifier being configured to classify air-entrained, crushed particulate material received from the pulveriser into a fine fraction which is expelled from the classifier and a coarse fraction which is returned to the pulveriser for further crushing, the classifier including:

- a housing defining:
  - an inward classification zone;
  - an inlet through which the entrained crushed particulate material received from the pulveriser enters the classification zone; and
  - an operatively upper exit defining an exit area for expelling the fine fraction and an operatively lower outlet which lead from the classification zone, and
- an open ended depending member which is at least partially disposed within the classification zone, the member having a narrow upper end and a lower end, the member diverging from the upper end toward the lower end, the upper end defining a mouth having a reduced cross-sectional area when compared with that of the exit area, wherein the upper end of the depending member is arranged within or below the exit area.

The depending member may be supported by a plurality of adjustable struts which permits a position of the depending member within the classification zone to be adjusted. The depending member may be in the form of a cone and the mouth of the depending member may be concentric with the upper exit such that the upper end is positioned in the middle of the upper exit. A length of the depending member, and hence the extent to which the depending member extends downwardly into the classification zone, may be adjustable.

The invention also extends to a method of modifying a classifier for use with a pulveriser, the classifier being configured to classify air-entrained, crushed particulate material received from the pulveriser into a fine fraction which is expelled from the classifier and a coarse fraction which is returned to the pulveriser for further crushing, the classifier including:

- a housing defining:
  - an inward classification zone;
  - an inlet through which the entrained crushed particulate material received from the pulveriser enters the classification zone; and
  - an operatively upper exit and an operatively lower outlet which lead from the classification zone, the method including:
- retrofitting a plurality of classifier inlet blades to an upper region of the classifier at or near the inlet, each blade including a body which comprises an operatively upstream portion which is outwardly disposed away from the inlet and an operatively downstream portion which is disposed at least partially within and/or above the inlet, at least part of the upstream portion of each blade being upwardly and inwardly inclined with respect to the blade body such that the blades are configured collectively to induce swirl and to direct the entrained particulate material into the classification zone.

An angular position of the inlet blades with respect to the housing may be adjustable.

The method may include retrofitting a plurality of pre-swirl vanes to the upper region of the classifier such that the vanes are arranged below the classifier inlet blades, each pre-swirl vane comprising a multi-planar body which includes an operatively upstream portion and an operatively downstream portion, the upstream and downstream portions being joined by a middle, the upstream portion being downwardly inclined with respect to the middle such that the upstream portion is substantially parallel to an incoming air stream in order to minimise air flow resistance and at least part of the downstream portion of each vane is upwardly and inwardly inclined with respect to the middle of the vane body to direct fluid flow inward and to induce a centrifugal swirl.

The method may further include retrofitting an appendage to an operatively lower edge of a member defining the upper exit of the classifier, the appendage having an aerofoil or teardrop cross-sectional profile.

BRIEF DESCRIPTION OF DRAWINGS

The invention will now be further described, by way of example, with reference to the accompanying drawings.

In the drawings:

FIG. **1** illustrates a longitudinal cross-section through a classifier in accordance with the invention;

FIG. **2** illustrates a face-on view of a classifier inlet blade which forms part of the classifier of FIG. **1**;

FIG. **3** shows a sectional top view of the blade of FIG. **2**;

FIG. **4** shows a three-dimensional view from below of an upper part of the classifier of FIG. **1**;

FIG. **5** illustrates a side view of part of an inner housing of the classifier including a plurality of pre-swirl vanes;

FIG. **6** illustrates a face-on view of one of the pre-swirl vanes shown in FIG. **5**;

FIG. **7** illustrates a three-dimensional view from above of the inner housing;

FIG. **8** shows a three-dimensional fragmentary view through the upper part of the classifier shown in FIG. **4**;

FIG. **9** shows, on an enlarged scale, part of a first embodiment of a lower edge of an exit pipe of the classifier;

FIG. **10** illustrates a second embodiment of the lower edge of the exit pipe;

FIG. **11** illustrates a partial sectional view of part of an upper region of an example embodiment of a classifier in accordance with the invention;

FIG. **12** illustrates a longitudinal cross-section through a further embodiment of a classifier in accordance with invention;

FIG. **13** shows a top view of a part conical member forming part of the classifier of FIG. **12**;

FIG. **14** shows a three-dimensional longitudinal section through the part conical member of FIG. **13**; and

FIG. **15** shows a longitudinal section through yet another embodiment of a classifier in accordance with the invention.

DETAILED DESCRIPTION OF AN EXAMPLE EMBODIMENT

In the figures, reference numeral **10** refers generally to a classifier in accordance with the invention. The classifier **10** is configured to classify air-entrained, crushed particulate material received from a pulveriser below (not shown) into a fine fraction which is expelled from the classifier **10** and a coarse fraction which is returned to the pulveriser for further crushing. The classifier **10** includes an outer body **12** which comprises an upper part **13** and a partially cone-shaped lower part **14**. The classifier **10** further includes an inner housing **15** which is concentrically arranged within the outer body **12**, the inner housing **15** defining an inward classification zone **19**. The inner housing **15** comprises an operatively upper cylindrical wall **17**, an upper periphery of which defines an inlet **20** which leads into the classification zone **19** and an operatively lower cone or grit funnel **21**. The classifier **10** further includes a cylindrical feed pipe **22** which extends lengthwise through the middle of the classifier **10** and defines a feed inlet **24** toward an operatively upper end of the pipe **22**. Raw material, for example coal, received into the feed pipe **22** via the feed inlet **24** is passed through the classifier **10** along an inlet axis X to the pulveriser (not shown) positioned below the classifier **10**.

The inner housing **15** is radially inwardly spaced from the outer body **12** and held fast by braces **26** which extend between the inner housing **15** and the outer body **12**. An airflow pathway **27** is defined between the inner housing **15** and the outer body **12** through which air-entrained crushed particulate material from the pulveriser is conveyed into the classification zone **19** via the inlet **20**. The classifier **10** further includes a cylindrical vortex finder or exit pipe **30** which is concentrically arranged about the feed pipe **22** and extends axially upward from the classification zone **19**. The feed pipe **22** and exit pipe **30** together define an annular exit passageway **31** whereby fine particulate material is transported to a desired location, e.g. in the case of coal to a furnace (not shown) for combustion.

Toward a lower end of the grit funnel **21** the classifier **10** has an annular rejection outlet **33** defined between an inner wall of the funnel **21** and a downwardly depending skirt **35** which is secured around a lower periphery of the feed pipe **22**. Coarse material, unsuitable for combustion, which has been separated owing to the classification action of the classifier **10**, is returned to the pulveriser via the rejection outlet **33** for regrinding.

The classifier **10** further includes a plurality of angularly spaced apart classifier inlet blades **37** which are arranged at least partially above the inlet **20** leading into the classification zone **19**, within an annular space defined by an inner surface of the upper part **13** of the outer body **12**, an outer surface of the exit pipe **30** and the upper periphery of the cylindrical wall **17**. The classifier **10** further includes a blade adjustment mechanism **39** in the form of a mechanical linkage which comprises a plurality of downwardly depending arms **42** (see FIG. **1** and FIG. **8**), upper ends of which are connected to an annular linkage by a short lever. Each arm **42** extends downwardly through the upper part **13** and engages a transversely extending blind slot **40** formed in each of the blades **37** (see FIG. **2**). In this configuration, axial rotation of the arm **42** results in angular displacement of the blade **37**. Accordingly, by adjusting the annular linkage, the angular position of each blade **37** can be adjusted in a synchronised manner. The blades **37** can be set between angles of about 30 to 60 degrees to a radial line passing through the centre of the classifier **10**.

Each inlet blade **37** comprises a generally planar body which is divided into an operatively upstream portion **43** which is outwardly disposed away from the inlet **20** (see FIGS. **1** and **2**) and an operatively downstream portion **44** which is inwardly disposed immediately above the inlet **20**. In addition, a lower corner **45** of the upstream portion **43** of each blade **37** is upwardly and inwardly inclined with respect to a remainder of the blade body. The lower corner **45** is inclined at an angle α (FIG. **3**) of between 20° and 40°

with respect to the remainder of the blade body when viewed edge-on from a top. In the example embodiment illustrated the angle α is 30°. The inclined lower corner **45** defines a fold line or bend line F which is substantially perpendicular to a diagonal line Z drawn between a pair of opposing corners of the blade **37** (FIG. **2**). Accordingly, the blade **37** is bent corner-to-corner. The remainder of the blade body is planar. The blades **37** are angularly spaced apart in a circular configuration such that the blades **37** collectively induce swirl or a centrifugal vortex and direct the entrained particulate material into the classification zone **19**. An operatively lower edge of each blade **37** is shaped to match the profile of the upper periphery of the cylindrical wall **17** and accordingly has a slanted step formed in the downstream portion **44** immediately after the fold line F.

In addition to the classifier inlet blades **37**, the classifier **10** further includes a plurality of pre-swirl vanes **47** (FIGS. **5** to **7**) which are disposed below the inlet blades **37** in the airflow pathway **27** defined between the inner housing **15** and the lower part **14** of the outer body **12**. The pre-swirl vanes **47** are therefore arranged operatively upstream of the inlet blades **37**. The vanes **47** are arranged about an outer periphery of the inner housing **15** at angularly spaced apart positions and project outwardly from the inner housing **15** to an inner surface of the outer body **12**. A conical gap **48** (see FIG. **11**) is formed between a radially outer edge of the vanes **47** and an inner surface of the lower part **14** of the outer body **12**. The radial width of the gap **48** can be varied in order to meet design requirements. The Applicant has noted that an increase in the radial width of the gap **48** up to half of a radial width of the pre-swirl vanes **47** increases the efficiency of the classifier. Each vane **47** extends downwardly from the upper periphery of the cylindrical wall **17**, at an inclined angle β relative to the vertical (FIG. **5**), over an intersection of the cylindrical wall **17** with the grit funnel or cone **21**. Referring to FIG. **6**, an operatively inner edge **50** of each vane **47** has a profile which matches that of the outer surface of the inner housing **15** and similarly an outer edge **52** is profiled to match the curvature of the inner surface of the outer body **12**. It is to be appreciated that the vanes **47** may be secured to either one of the inner housing **15** or outer body **12** or both. In the example embodiment illustrated the angle β is 45°.

Still referring to FIG. **6**, each vane **47** has a multi-planar body which comprises an operatively upstream portion **53** and an operatively downstream portion **54**, the upstream portion **53** and downstream portion **54** being joined by a planar middle **55**. The upstream portion **53** is downwardly inclined with respect to the middle **55** such that the upstream portion **53** is substantially parallel to an incoming air stream in order to minimise air flow resistance. In this example embodiment, the upstream portion **53** is downwardly inclined at an angle θ of 30° relative to the middle **55** (see FIG. **5**). The angle θ is dependent upon inlet flow conditions and may vary depending on the application. Furthermore, an outer corner **51** of the downstream portion **54** is upwardly and inwardly inclined with respect to the middle **55** at an angle of 30° relative to a plane of the middle **55**. Note that the angle of the outer corner **51** is designed to suit flow conditions at the upstream portion **43** of the blades **37** positioned above the vanes **47**. The outer corner **51** serves to direct fluid flow inward and to induce a centrifugal vortex or swirl. A fold line or bend line representing an intersection of the middle **55** and the upstream portion **53** is parallel with a lower edge of the upstream portion **53**.

Referring now to FIGS. **8** and **9**, an operatively lower edge of the vortex finder or exit pipe **30** which, together with the feed pipe **22** defines the annular exit passageway **31** has a downwardly facing, teardrop or aerofoil cross-sectional profile **57**. The aerofoil profile **57** reduces turbulence and flow resistance at the exit. The lower edge is formed by attaching a ring-shaped member **60** having a round cross-sectional profile to the exit pipe **30**. The teardrop profile **57** is completed by securing an inner skirt **61** and an outer skirt **62** to respective sides of the ring-shaped member **60** and the exit pipe **30**, at an angle thereto. Each skirt **61**, **62** is in the form of a curved strip of metal which is secured to a side of the ring-shaped member **60**. Understandably, both the ring-shaped member **60** and the skirts **61**, **62** may be segmented into, for example, four or eight equally sized segments in order to facilitate easy installation. In order to further simplify installation, the teardrop shaped lower edge may be preassembled by securing it to a length of pipe, the dimensions of which match those of the exit pipe **30** such that the length of pipe can simply be appended to the exit pipe **30**. In a first embodiment of the teardrop shaped lower edge illustrated in FIGS. **8** and **9**, the teardrop shaped profile **57** is orientated vertically downward. In a second embodiment illustrated in FIG. **10**, the ring-shaped member **60** is outwardly disposed relative to an edge of the exit pipe **30** such that the inner skirt **61** is substantially upright and the outer skirt **62** is slanted. This configuration illustrated in FIG. **10** will be used where a gap between the exit pipe **30** and the feed pipe **22** is small resulting in a too high exit velocity.

A further embodiment of a classifier in accordance with the invention is illustrated in FIG. **12** and is designated by reference numeral **100**. Like reference numerals have been used to refer to similar features of the classifier **100**. The classifier **100** is similar to the classifier **10** described earlier, but includes an additional part conical member **102** which is concentrically arranged about the feed pipe **22** and is disposed immediately below the vortex finder **30**. An operatively upper periphery of the conical member **102** is positioned in, or immediately below, the exit passageway **31** defined by the vortex finder **30**. The upper periphery of the conical member **102** defines an annular mouth **105** which ideally occupies half of a cross-sectional area of the exit passageway **31**. The part conical member **102** includes a cone **103** which diverges toward the bottom and leads into a cylindrical skirt **104** having a tear drop profiled lower periphery **107** which corresponds with the profile **57** of the vortex finder **30**.

A height of the conical member **102** with respect to the vortex finder **30** is adjustable by increasing/decreasing a length of adjustable struts **109** secured to an upper part of the cone **103**. The conical member **102** is also supported by external struts **110** connecting the cone **103** to the inner housing **15**. A pair of three angularly spaced apart inclined braces **112**, each of which is connected to the feed pipe **22**, support the conical member **102** from the inside (see FIGS. **13** and **14**). Although this has not been clearly illustrated, a length of the conical member **102** may be adjustable in order to optimise efficiency of the classifier **100**.

An alternative embodiment of the classifier in accordance with the invention is illustrated in FIG. **15** and is designated by reference numeral **200**. The classifier **200** is essentially the same as the classifier **100** but instead of the part conical member **102**, the classifier **200** includes a cone **202** which is concentrically arranged about the feed pipe **22** such that an upper periphery of the cone **202** is arranged within or immediately below the vortex finder **30** and defines a mouth **105** which ideally occupies half of a cross-sectional area of the exit passageway **31**. The cone **202** diverges toward the bottom. The cone **202** is suspended in place by braces and struts and accordingly, the position of the cone **202** with respect to the vortex finder **30** and a length of the cone **202** may be adjustable in order to achieve a desired outlet particle size exiting the classifier **200**.

In use, air-entrained, crushed particulate material received from the pulveriser is directed along the airflow pathway **27** and passes through the pre-swirl vanes **47**. The upstream portion **53** of each vane **47** is downwardly directed in the direction of the airflow such that it is substantially parallel with the flow direction of the incident particles in order to minimise flow resistance and wear. The particles then encounter the inclined middle **55** of the vane **47** which induces a vortex. Finally, as the particles pass the downstream portion **54**, the upwardly and inwardly inclined outer corner **51** or upper kink forces the particles inward toward the classifier inlet blades **37** above.

The adjustable inlet blades **37** receive the airflow from the vanes **47** below in an upward and inward direction. The lower corner **45** of each blade **37** is angled or kinked to allow smooth inlet flow conditions into the blades **37**. The angle of the blades **37** is adjustable by manipulating the blade adjustment mechanism **39** in order to regulate swirl and product fineness. The blade length is determined using velocity requirements at the blade outlet to set swirl conditions to suit fineness adjustability. The airstream is then directed into the classification zone **19** via the inlet **20** where it is subjected to classification action. The lower edge of the exit pipe or vortex finder **30** which has a teardrop or aerofoil profile **57** then receives the fine particles entrained in an upward airflow flowing along the exit passageway **31**. In previous designs, this lower edge was plain or manufactured from two inverted cones and produced turbulence around its lower periphery which resulted in resistance losses. The teardrop or aerofoil profile **57** reduces flow separation and resultant resistance losses.

In respect of the classifiers **100**, **200**, the conical members **102**, **202** improve efficiency of the classifier and hence product fineness. If it is desirable to increase particle size, the length of the conical member **102** can be reduced, hence increasing a gap between the grit funnel **21** and the lower periphery **107**. Also, by lowering the position of the conical member **102** with respect to the vortex finder **30**, the resultant particle size will be increased. The performance of the classifiers **100**, **200** can therefore be fine tuned by adjusting the position and length of the conical members **102**, **202**.

The Inventors believe that by introducing the above design modifications, the throughput of the classifier **10**, **100**, **200** can be improved by a significant percentage (e.g. 15%) or product fineness improved at similar resistances over existing designs. The inlet blades **37**, pre-swirl vanes **47**, modified vortex finder **57** and conical members **102**/**202** serve to improve efficiency and reduce resistance to flow throughout the classifier **10** hence improving throughput capabilities or product fineness at similar resistances which suits low NO_x requirements of present boilers.

The invention claimed is:

1. A classifier for use with a pulveriser which is configured to crush raw material, the classifier being configured to classify air-entrained, crushed particulate material received from the pulveriser into a fine fraction which is expelled from the classifier and a coarse fraction which is returned to the pulveriser for further crushing, the classifier including:

a housing defining:

an inward classification zone;

an inlet through which the entrained crushed particulate material received from the pulveriser enters the classification zone; and

an operatively upper exit and an operatively lower outlet which lead from the classification zone;

a plurality of classifier inlet blades which are arranged at or near the inlet; and

a plurality of angularly spaced apart, inclined pre-swirl vanes which are disposed upstream of the inlet blades, wherein each pre-swirl vane comprises a multi-planar body, wherein the pre-swirl vanes are disposed around an upper region of an outer periphery of walls of the housing defining the classification zone and wherein the multi-planar body of each vane includes an operatively upstream portion and an operatively downstream portion, the upstream and downstream portions being joined by a middle, wherein the upstream portion is downwardly inclined with respect to the middle such that the upstream portion is substantially parallel to an incoming air stream in order to minimize air flow resistance and wear; and at least part of the downstream portion is upwardly and inwardly inclined with respect to the middle and configured to direct fluid flow inward and to induce a centrifugal swirl.

2. A classifier as claimed in claim **1**, wherein the upstream portion of each vane is downwardly inclined at an angle of between 20° and 40° relative to the middle of the vane body and wherein a fold line or bend line representing a start of the upstream portion is parallel with a lower edge of the upstream portion, wherein an outer corner of the downstream portion of each vane is inclined at an angle between 20° and 40° with respect to the middle of the vane body, wherein the middle of each vane body is inclined at between 30° and 60° with respect to the vertical and wherein inner and outer edges of each vane match profiles of neighbouring walls of the classifier and wherein a gap is defined between the outer edges of the vanes and a mill body, the gap being smaller than or equal to half a width of a pre-swirl vane.

3. A classifier as claimed in claim **1**, wherein there is at least one inlet blade for every two pre-swirl vanes.

4. A classifier as claimed in claim **1**, wherein the pre-swirl vanes have a vane-to-vane overlap of at least one third of a vane breadth.

5. A classifier as claimed in claim **1**, wherein a lower edge of the housing defining the upper exit has an aerofoil or teardrop cross-sectional profile which is configured to reduce turbulence and flow resistance at the exit of the classifier.

6. A classifier as claimed in claim **1**, which includes an open ended depending member which is at least partially disposed within the classification zone, the member having a narrow upper end and a lower end, the member diverging from the upper end toward the lower end, the upper end defining a mouth having a reduced cross-sectional area when compared with a cross-sectional area of the upper exit, wherein the upper end of the depending member is arranged within or below the upper exit.

7. A classifier as claimed in claim **6**, wherein the depending member is supported by a plurality of adjustable struts which permits a position of the depending member within the classification zone to be adjusted.

8. A classifier as claimed in claim **7**, wherein the depending member is in the form of a cone and the mouth of the depending member is concentric with the upper exit such that the upper end is positioned in the middle of the upper exit.

9. A classifier as claimed in claim **8**, wherein a length of the depending member, and hence the extent to which the depending member extends downwardly into the classification zone, is adjustable.

10. A classifier as claimed in claim **1**, wherein the classifier inlet blades are adjustable, each adjustable blade including a body which comprises an operatively upstream portion which is outwardly disposed away from the inlet and an operatively downstream portion which is disposed at least partially within and/or immediately above the inlet,

wherein at least part of the upstream portion of each adjustable blade is inclined with respect to the downstream portion of the blade body, the adjustable blades collectively being configured to induce swirl and to direct the entrained particulate material through the inlet into the classification zone.

11. A classifier as claimed in claim **10**, wherein the classifier is a static classifier and a corner of the upstream portion of each blade is inclined at an angle of between 20° and 40° with respect to the downstream portion of the blade body when viewed edge-on from a bottom of the blade body and wherein the corner of the upstream portion is separated from a remainder of the blade body by a fold line or bend line which is substantially perpendicular to a diagonal extending between a pair of opposing corners of the blade body.

12. A classifier as claimed in claim **10**, wherein each adjustable blade includes a mounting formation whereby the blade is mounted to the housing and which includes an inlet blade adjustment mechanism which is connected to the mounting formations of each of the blades in a configuration in which an angle of each blade body relative to the housing is adjustable in order to regulate air flow through the inlet, by adjusting the blade adjustment mechanism.

13. A classifier as claimed in claim **12**, wherein, in use, an air/particle velocity through the blades is between 4.5 and 5.5 m/s.

14. A classifier for use with a pulveriser which is configured to crush raw material, the classifier being configured to classify air-entrained, crushed particulate material from the pulveriser into a fine fraction which is expelled from the classifier and a coarse fraction which is returned to the pulveriser for further crushing, the classifier including:

a housing defining:

an inward classification zone;

an inlet through which the entrained crushed particulate material received from the pulveriser enters the classification zone;

an operatively upper exit and an operatively lower outlet which lead from the classification zone;

a plurality of classifier inlet blades which are arranged at or near the inlet; and

a plurality of angularly spaced-apart inclined pre-swirl vanes which are disposed upstream of the inlet blades, wherein each pre-swirl vane comprises a multi-planar body, the classifier inlet blades being adjustable, each adjustable blade including a body which comprises an operatively upstream portion which is outwardly disposed away from the inlet and an operatively downstream portion which is disposed at least partially within and/or immediately above the inlet; wherein at least part of the upstream portion of each adjustable blade is inclined with respect to the downstream portion of the blade body, the adjustable blades collectively being configured to induce swirl and to direct the entrained particulate material through the inlet into the classification zone, the classifier being a static classifier and a corner of the upstream portion of each blade being inclined at an angle of between 20° and 40° with respect to the downstream portion of the blade body when viewed edge-on from a bottom of the blade body and wherein the corner of the upstream portion is separated from a remainder of the blade body by a fold line or bend line which is substantially perpendicular to a diagonal extending between a pair of opposing corners of the blade body.

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